Current Status and Prospect for EUV Lithography at Univ. of Hyogo

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First extreme ultraviolet lithography (EUVL) called X-ray projection lithography when the beginning of its technology had been invented by the research group of NTT in Japan. After 30 years later, extreme ultraviolet lithography has been adapted to use for manufacturing (HVM) logic devices since 2019. The R&D activities of EUVL will be introduced and prospect for advanced EUVL will be discussed.

Research group of Himeji Institute of Technology (present University of Hyogo) begin to start the R&D from 1996. It was designed the three-aspherical-imaging optics based on the Offner-type optics to expand the exposure area on a wafer for the practical usage. And employing synchronized scanning between a mask and wafer. This exposure tool named ETS-1 employes this imaging optics collaboration with Hitachi Central Research Lab. And Nikon. Using this tool 60 nm line and space pattern with an exposure area of 10 mm x 10 mm in size was demonstrated in 2001 at the beamline BL09 of NewSUBARU synchrotron light facility. Our group leaded four Japanese EUVL project for 21 years period such as ASET, SELETE, EUVA, EIDEC.

NewSUBARU is the largest synchrotron which is operated by university in Japan. Now nine beamlines are operated and three beamlines are using for the R&D of EUVL. Photograph of the NewSUBARU Synchrotron light facility including its specific 1.0-GeV-electron-beam c-band injector are shown in Fig.1.

Figure 1: Photograph of the NewSUBARU Synchrotron light facility including its specific 1.0-GeV-electron-beam c-band injector.

Using these beamlines, resist fundamental study, mask inspection, optical element metrology has been carried out. Inspection equipment, exposure equipment, etc. are shown below.

For Resist

- ✓ BEUV & EUV sensitivity and outgassing measurement
- ✓ Total Electron Yield (TEY) for the chemical reaction analysis for EUV resists
- ✓ EUV & BEUV absorption measurement for high sensitivity
- ✓ Patterning by EUV interference lithography
- ✓ Chemical-Uniformity Evaluation by RSoXS, and PEEM
- ✓ 2ndry electron energy distribution analysis and low 2ndry electron chemical behavior

For Optics (Mask, Pellicle, etc.)

- ✓ EUV & BEUV MLs Reflectance measurement
- ✓ Reflectance of Large optics (~ϕ800 mm) for collector mirror of EUV LPP light source
- ✓ EUV Transmittance measurement of pellicles
- ✓ EUV coherent scatterometry microscope (CSM) for the mask defect inspection
- ✓ High harmonic gas laser adapted to EUV CSM
- ✓ EUV scattering measurement
- ✓ EUV optical index for new absorber (high k and low k materials)
- ✓ Out-of-band reflectometer
- ✓ EUV durability in H_2 / H_2O

Now many significant technical issues are remained such as resist with simultaneous achievement of high resolution, high sensitivity and low line width roughness (LWR), defect free mask and pellicle with long life time maintain high transmittance, and EUV source power > 1 kW in high stability.

The highest priority is EUV resist development which satisfies above characteristic simultaneously. Many types of EUV resist have been introduced such as chemically amplified resist (CAR), non-CAR, metal oxide resist (MOR), and dry resist. All these resists do not still satisfy the required LWR. The chemical stochastic analysis is essential to achieve low LWR. The origins of the stochastic are shown below. Especially, the chemical contents spatial distribution has not been analyzed yet. Resonant soft X-ray scattering (RSoXS) in reflection and transmission modes are very helpful analysis method for the spatial distribution analysis of chemical contents in the resist thin film.

More fundamental studies of both for EUVL and advanced EUVL are necessary.

- ✓ Spatial concentration distribution of resist components (base resin, photosensitive material, etc.)
- ✓ Shot noise due to EUV light which has photon energy of 91.8 eV
- ✓ Spatial spread of photo electron generation by EUV light irradiation (photo electron blur)
- ✓ Diffusion of acid during PEB due to residual solvent in the prebake process in the case of CAR
- ✓ Effects during development and rinsing Effects
- ✓ Pattern collapse, pattern stripping, microbridge defect
- ✓ Lithography impact by OoB light generated from LPP EUV source

Acknowledgement

I appreciate Prof. Tetsuo Harada (University of Hyogo) and Associate Prof. Shinji Yamakawa (University of Hyogo) for their great support of EUVL research works.